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Abstract

Competence development of knowledge workers is a primary concern at the crossroads between human resource development (HRD) and knowledge management. HRD needs to facilitate competence development for self-organised knowledge workers and to align it with organisational goals. The aim of this paper is to support decision makers in allocating knowledge management and e-learning efforts in HRD. Motivated by a case study and its identified knowledge work practices, we propose a mathematical model optimising the allocation of workers to competence development measures. The suggested model is intended to support HRD decision making. Moreover, the paper discusses challenges of the identified knowledge work practice that could not be addressed and presents suggestions for extensions of the model that may solve these additional challenges.

1 Introduction

In knowledge management (KM) [17] the research areas of competence management (CM) and e-learning support identification and transfer of knowledge and help to focus on skill development of workers [11]. Successful management of knowledge transfer is difficult [3] and a greater emphasis on the development of individual competences means a greater demand on the effort, flexibility and motivation of the employees and human resource development (HRD) professionals [5]. Besides, distinctive organisational competences are deemed fundamental for the success of knowledge intensive organisations [14], which requires a refined HRD approach with traceable and justifiable decisions.

Competence development of knowledge workers is a primary concern in KM, no matter whether an organisation pursues a codification or a personalisation strategy [19]. In the case of a personalisation strategy, the individual knowledge worker and her competencies are focused, and knowledge transfer is facilitated primarily directly between people. This emphasises the importance of knowledge workers' competencies and their individual development so that they are prepared to take on novel problems in situations that are highly complex and less foreseeable. In the case of a codification strategy, competencies of knowledge workers are developed with an emphasis on documented knowledge as an instrument to support this process and a focus on rolling out so that they can be administered and applied repeatedly by knowledge workers for problems that are (partially) known with a high chance of success in explicitly specified contexts. In both cases, allocating measures to develop competencies of knowledge workers is crucial. The fact that knowledge workers often know themselves best about the problems they encounter and are well trained to act in a self-organised way, HRD needs a well-defined process to allocate resources to knowledge workers to justify its decisions and negotiate them with an increasingly self-conscious clientele. There is an increasing amount of data available about knowledge workers' competencies in organizations as well as about documented learning measures. Also, HRD needs to facilitate partly self-organised competence development and to align it with organisational goals, concretely selecting directions of competence development. These developments taken together, render it worthwhile to support these complex decisions to increase the visibility of the decision process, level of justification and potentially commitment towards the resulting resource allocations. Also from the workers' perspective such an approach is valued if the preferences for learning and improving competences are deliberated. By involving workers in the competence development, their commitment to the organisation, motivation, productivity and thus the success of a project, as well as the innovativeness are known to be improved [7,10,44].

This paper focuses on the investigation of these KM aspects and is placed at the intersection of HRD and CM. The aim is to investigate the decision process allocating learning measures to employees to achieve required competences on a certain level. Due to the high complexity and the strategic dimension of the underlying decision, a complete quantification and automation of the decision seems impossible. However, pre-structuring the decision problem and formally describing the main determinants is a first important step to help evaluate decision alternatives and provide traceable and justifiable arguments for allocating learning measures to knowledge workers. The ambition is to enhance the decision quality rather than to automate the decision problem [1].

In the following article, we first describe a case study performed in two organisations that provided a detailed account of a work practice that allows us to illustrate how the intended decision support in HRD helps solving a practical problem in the described context (Section 2) followed by a positioning of the analysed work practice. Subsequently, we give an overview of constructs identified in related research and propos an optimisation model (Section 3). The discussion (Section 4) outlines additional challenges in HRD that could not be addressed in the model and presents suggestions for extensions that may solve these additional challenges. The paper finishes with the conclusion (Section 5).

2 Case study

We performed a case study in two medium-sized organisations [29]. Goal of the study was to receive a deeper understanding of current knowledge work processes or practices (such as the ones described in [9]), informing practices found in an ethnographic study [39], self-organised workplace learning patterns [35], CM processes as developed in a case study approach [25] and, more concretely, the work practice “training” found in an empirical study based on semi-structured interviews [21]. Beyond that, the goal was to identify challenges in the mentioned domains from an information and communication technology perspective[42]. Both studied organisations were chosen for the analysis due to the fact that they have a strong affinity to learning, consider themselves as knowledge-intensive organisation [2], operate in high-tech knowledge-intensive service sectors [12], use ICT in KM and have institutionalised e-learning and CM initiatives. In one of the organisations, employees use their personal learning and workplace environment on a daily basis and get tasks, learning objectives and learning measures assigned via this system. All employees participate in an organisational and personal CM system which lets employees edit their competency profiles, perform tests and show their interests in developing themselves with certain goals in mind.

2.1 Study design

The data collection approach chosen was semi-structured interviews with 11 persons working in the organisational units of information technology (IT), human resource management (HRM), legal and general issues, technology and project management, accounting, technology, art/creative, business, and content management. The basis for the interviews was an interviewer guideline comprising 16 open-ended questions covering the domains of business process management and HRM, with emphasis on CM, KM, and innovation management. The question regarding ICT support was always included to determine which processes are supported with a decision support system (DSS). The data gained from the interviews was analysed using the scenario technique [34] and resulted in eight current knowledge work practices (KWP). These KWPs were developed according to the emphasis made by interviewees and the subsequent exploitation of transcriptions by researchers. They include sequences of actions, behaviour of actors, changes in the setting, or the like. The KWPs showed the dynamic work environment of knowledge workers and depicted the constantly changing organisational requirements and a need for flexible assignment of tasks from multiple organisational units. We here refine one of these KWP, namely the assigning of learning measures to knowledge workers, and illustrate it in the organisational scenario.

2.2 Scenario

The assignment of project tasks to workers is a regular challenge for the HR manager in the organisation studied. Together with the team leader or project manager, she exploits the CM tool, where all employees are encouraged to keep track of their competences, to see if a person with the requested competence is available. Only if the required competences are present in the company, the project can start. Otherwise, the HR department in coordination with the project manager has to organise learning activities to create or improve a workers’ competence to fill the competence gap. The option of employing new workers is only considered if none of the employees is available. This decision on whom to train is made by looking through workers’ competence profiles and performing a manual competence gap analysis, meaning the

identification of a person which would fit to the job and has competence gaps that are able to fill in the given time. If the person agrees to the development and staffing decision, the person gets assigned learning modules on the organisation's e-learning platform followed by an assessment. Of course, there are also competence development measures outside the organisation's e-learning system, which can be assigned and the worker is encouraged to contact colleagues in case of particular questions.

2.3 Assigning learning measures

As the KWP in the case study outlined (Section 2), HRD is challenged in the process of staffing a project team, and beyond. The key question that arises and that we address is:

Which learning measures should be performed by which worker to develop a required competence?

Figure 1 depicts the identified constructs of the KWP with relations between them and highlights the challenges of our model that are represented by the relations/interactions among concepts.

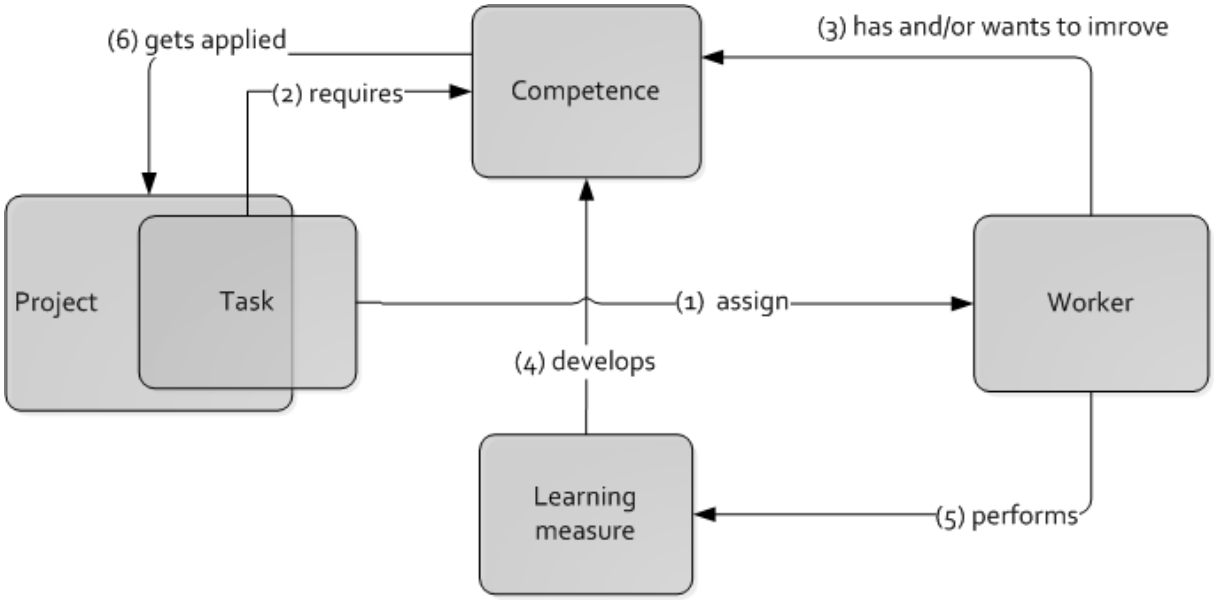

Figure 1: Human resource development knowledge work practice

To *assign a task* (1) which *requires certain competences* on a defined level (2) to a worker, the worker has to *have these required competences* (3). If no worker with the required competences is available to perform the task a worker has to be chosen to improve or develop the needed competence. The development of a competence is performed with *learning measures designed for a competence* (4) to reach a particular competence level. Different learning measures for competence development on and for a certain level are available inside or outside the organisation. Learning measures *get performed* (5) by workers which causes costs. The arising costs need to be smaller than all benefits gained in the projects in which the competence *gets applied* by the worker (6). Thus, a complex decision problem arises.

Within the following section these constructs in respect to the KWP are discussed and an optimisation model for this decision problem will be introduced.

3 Model

From the case study's results of the current HRD practice we break down the process and address the key decision of which worker to assign to what competence development measure. Taking up the challenges and interactions outlined in figure 1, we look closer at the four main constructs in this decision process: *competences* owned by *knowledge workers*, *learning measures* applied to develop competences that are required for *tasks* in projects.

- Competence: The distinction between the terms skills, qualification and competence of a worker can be examined in several ways. Qualifications represent descriptive educational learning objectives which are taught in traditional pedagogical settings like training courses. In contrast, competences include the dispositional ability to efficiently/proficiently act in complex situations and specific to a particular context. We define competence as a combination of knowledge, skill and attitude, following the classic learning structuring method of the "Knowledge Skill Attitude" approach [15]. The notion of skill refers to a specific ability required in undertaking a task, while knowledge refers to contextualised set of information required to undertake a task. Attitudes are cognitive or relational capacities on undertaking a given type of task and assignment.
- Learning measure: In the context of this paper, a learning measure is defined as an activity that leads to the development or improvement of a competence of a worker. Such a measure can represent a formal or informal learning activity [3]. In the KWP discussed, learning measures are managed in a learning management system (LMS) and are one or a sum of e-learning courses, workplace learning, formal or informal trainings inside or outside the organisation. To decide what competences to develop of a certain worker one needs to know what learning measures are available to develop the particular competence as well as what previous knowledge the worker requires. We suggest addressing learning measures directly to competence levels. By matching the competence levels of the worker and the learning measure, a basic fit would denote that the worker could follow the given input.
- Knowledge worker: Generally, knowledge workers are distinguished from non-knowledge workers by their abstract knowledge which requires high levels of formal education, and their production of new knowledge rather than merely application of existing knowledge [40]. Knowledge workers are used to learning and improving their competences to solve their everyday complex, ill-structured problems [31]. Their motivation and productivity and hence, the success of projects where they are involved in, depend on the organisations ability to address their learning preferences [7,10].
- Task in a project: Project management work is structured with tasks assigned to workers to perform or be responsible for them. Either way, certain competences are necessary to successfully cope with the challenges of a task [23]. The analysis becomes more difficult, the more complex a task gets. Especially in knowledge work, such determination of exact requirements is difficult due to the complex and poorly structured problems knowledge workers face. While this "input" is difficult to define, the outputs and benefits of a task needs to be calculated and foreseen.

Understanding these main constructs of the KWP, we define the main variables relevant for the decision problem identified within the case study and grounded the paper in the related literature.

Decision variable: The main assignment question of the model is: which knowledge worker should perform which measure? Due to the fact that a measure can be assigned to several knowledge workers and that several measures can be assigned to a single knowledge worker, an assignment problem $X_{W,M}$ with the following two dimensions occurs: (1) knowledge worker and (2) learning measure. Such assignments cannot be performed partially and hence is represented by a Boolean decision variable. Consequently, the assignment decision differentiates two cases: $X_{W,M} = 1$ a measure is assigned to a knowledge worker or $X_{W,M} = 0$ the measure is not assigned to a knowledge worker. Hence, the decision variable X is formally defined as the following:

$$X_{W,M} \in \{0,1\}$$

Costs: Due to the fact that financial resources are limited in organisations, costs of learning measures need to be considered. Costs can be calculated on different levels of detail and can comprise the following aspects: the price quoted for the measure, costs of facilities, infrastructure, licenses for software needed, costs to design and develop the measure, average hourly salary of participants multiplied by hours needed for measure, and costs for participants traveling [16,41]. Due to the fact that costs depend on the worker performing a measure, (e.g., the hourly salary of the worker and costs for the measure itself the costs are determined in dependence of both variables). The costs are represented in a currency (i.e., a real number), as formally defined as:

$$Cost_{W,M} \in R$$

Benefit: A variable representing the benefit of a competence on a certain level and hence the assignment of a measure to a worker is required to balance the positive and the negative impact of the decision. The idea of showing the value of competence development was derived from the idea of intellectual capital [20]. It has been shown that the success and the competitive advantage of a knowledge organisation relies on its human resources and their competences when performing tasks that bring benefit [3]. Again the benefit for an organisation can be measured on different levels of details containing, for example, the following aspects: savings due to efficiency increases, higher quality, better work habits, work climate, higher worker satisfaction, better customer service, more successful employee development and more initiative and innovation [16,41]. Competences on a predefined level are primarily interesting for the realisation of projects rather than individual persons. Hence, the determination of benefits in dependence to competence levels is sufficient. Benefit is also represented as a currency value, to compare the benefit with the costs. Benefit is formally defined as:

$$B_{C,L} \in R$$

Consequently, an assignment of measures to competence levels is needed to relate costs and benefits to each other. Due to the three dimensions: measure, competence, and level, a decision cube with Boolean assignments is necessary. The mapping is formally defined as:

$$Mapping_{M,C,L} \in \{0,1\}$$

Preference: Learning, here understood as the performance of measures, is no mechanistic process and requires the learner's willingness. The willingness to perform a measure and to acquire a competence on a certain level is determined by the worker's preference and represents the worker's anticipated benefits from the performance of the measure [7,10].

To ensure that the preference can be related to the benefit and the cost, it is also represented as a currency value. Furthermore, it is assumed that each knowledge worker has a certain budget he can allocate to the most preferred competences. The preference is formally defined as the following:

$$P_{W,C,L} \in R$$

Time: Measures differ in the time required to create a competence, as well as in the time a competence may endure as a basis for competitive success. Some competences may endure longer than others, may require less frequent modification than others, or may commit a firm's capabilities to actions with longer planning horizons than others [37,41]. Hence, it is necessary to assign a time needed to perform a learning measure to every measure, which is formally defined as the following:

$$MTime_M \in R$$

Every worker also has a limited time frame for the consumption of measures. The maximal time a worker can spend for measures can differ from worker to worker. It is also represented as real value and formally defined as:

$$MTime_W \in R$$

Competence level: Measures are intended to increase the knowledge workers competence level and can require a minimal level of competence to ensure a workers ability to follow the learning measure [11]. Hence, the level of competence must be known to assign measures to knowledge workers, in an appropriate manner. The assignment, if a worker has a competence on a certain level, is a Boolean expression. The competence is formally defined as:

$$W_{C,L} \in \{0,1\}$$

Accordingly a measure needs a minimal required level of expertise that is also represented by a competence level, and formally defined as the following:

$$MMin_{C,L} \in \{0,1\}$$

Target function: The target function contains the decision matrix that is multiplied with the result from its associated preferences, benefits and costs. Due to the fact that the preferences and the benefits are related to the competence level, they need to be multiplied with the mapping cube associating measures with competence levels.

$$\boldsymbol{U = \sum_{w=1} \sum_{m=1} X_{W,M} * (\sum_{c=1} \sum_{l=1} Mapping_{M,C,L}(P_{W,C,L} + B_{C,L}) - Cost_{W,M}) \rightarrow \max} \quad (1)$$

Constraints: The first constraint is that the sum of the time the assigned measures require for a knowledge worker is smaller or equal to the worker's available time:

$$\boldsymbol{\sum_{w=1} \sum_{m=1} X_{W,M} * MTime_M \leq WTime_{C,L}, \forall W} \quad (2)$$

The second constraint has to ensure that the knowledge worker has the minimal required competence level for every assigned measure:

$$\boldsymbol{X_{W,M} * W_{C,L} = X_{W,M} * MMin_{C,L}, \forall W} \quad (3)$$

The introduced optimisation model is a linear model. Due to the fact that the decision variables are restricted to the values 0 and 1, the presented decision model can be classified as an integer programming problem, and, more specifically, as a zero-one programming problem [8]. More specifically, the problem can be classified as an assignment problem in the field of combinatorial optimisation, where learning measures are assigned to employees [45].

We examined approaches for similar problems described in the literature. The worker to task assignment problem from a competence perspective aims at improving the department utilisation by enhancing the workforce flexibility [38]. The assignment of competencies to workers as well as to tasks performed in departments can be found here as well. Another approach focusses on the project portfolio selection considering competence based goals [18]. Here the competencies of employees as well as the needed competences in projects overlap to our proposed model. The assignment of workers to various workplaces taking knowledge transfer and learning goals into account is also used by an optimization approach [30]. Here, the assignment of competencies considering also the competency level as well as learning preferences overlap with our mode. Finally, an assignment model of competence sets for decision making [27] could be found in which competences are assigned to deciders. None of these approaches could be applied to the problem identified in the introduced scenario. However, the literature review showed that the application of decision models to target competence related assignment problems in general is not new and that the usage of optimization models is feasible. However, it came across that all identified decision models address specific problems identified in cases. General model elements, such as employees and their competence levels or preferences could be found in the related literature and were reused. Very generic model elements, such as time or costs can be found in the related literature as well, but their definition needs to be aligned with each problem domain. For example costs in [30] occur from moving from one workplace to another workplace which cannot applied to the underlying scenario.

4 Discussion

We are revisiting a well-known problem of HRD that is so far only weakly supported by DSS (Section 3). Due to rising technology standards in HRM, for example, CM ontologies [36,44], and as a result of more available data about employees' activities in general as well as profiles and traces they leave in CM systems, we argue that it is beneficial to undertake the challenge of providing a DSS in HRD. However, there are still several individual, organisational or technical constraints. Here we focus on such constraints, identify the consequences, and point out our new understanding of the problem. The discussion is based on the proposed model and relates the identified challenges to the existing body of literature. The goal of the discussion is to identify implications for the KWP described in Section 2.3, as well as for the design of an ICT support, and to disclose limitations of the current model.

Competence determination: A considerable challenge in CM systems is to keep workers' competences up to date. While the initial definition of competences and competence levels and the first collection of competences were successfully done in one of the organisations analysed in our case study, the updating of every worker's competences on a regular basis is still causing difficulties. Beside mandatory or optional assessment tests, personal profile updates by the worker, HRD or supervisor, there is also the approach to gain insights on persons' competences by analysing workers' social network activities, comprising blog and forum posts, persons

contacted, wiki articles and documents created or edited [28,32]. The challenge is to enrich direct competence assessment with competence ascription from behaviour that left traces in IT to receive better understanding in learning habits and to keep competence profiles up to date. This investigation would impact connection (3) between workers and competences in figure 1.

In order to determine which competencies to build by individual workers, an organisation needs to develop a knowledge strategy identifying a knowledge gap between what a firm must know and what a firm knows on an organisational level [43]. The core competency approach [33] might help to further focus on those competencies that are considered most important for the organisation's core business value proposition. This would impact our model with additional decision criteria for the learning measure – worker assignment (figure 1 – (5)). Core competences are created through the connections between the organisation's objectives, strategy, structure and culture, as well as its management concepts. Thus, to decide what workers' competences to develop the definition of core competences is necessary [5,26], although the relationship between these concepts is not a direct one.

Worker's allocation in project: Relating measures and hence competencies to employees can also be performed independently from their assignment to projects. For example, it could happen that employees holding needed competences for a project are not available for a certain and possibly critical period of time. Due to the missing competence in the project, no or a substantially lower benefit for the project can be generated and hence the estimation of benefit is not correct. Cost could arise due to time delays in the project realization. The solution would be to integrate the assignments of employees to projects also into the model. The integration of this aspect would lead to several model problems, however, and due to many imponderables, the scheduling of employees of such a long period, i.e. performance of measures and project duration does not seem feasible. However, if organisations work with such exact worker to project planning this addition would refine and impact the assigned workers to tasks/projects, depicted with (1) in figure 1.

Benefits and Costs: The model does not give an answer to the question how tangible and intangible benefit of competence development are monetarily measured, if benefit or cost function are linear or non-linear, and if different persons cause different benefit for the organisation if they train the same competence. Approaches to answer these questions are discussed in learning analytics research literature [6] and return on investment frameworks for trainings [4,6,13,16,22,24]. As mandatory in linear optimisation models, linearity of benefits as well as of costs is assumed. However, the benefits and costs of competence development are not necessarily linear. For example, the benefit of the first employee acquiring a competence might be higher or lower than the benefit of further employees acquiring this competence (saturation versus critical mass and complementarity). Similar arguments can be made about costs. The organisation performing the KWP in our case study noted that it is especially the first few workers performing a learning measure that can cause additional costs due to the reason that, for example, e-learning modules do not meet the exact learning goals and need additional adaptation. These aspects cause non-linearity problems of the model that cannot easily be handled and could not be formulated as static value. It seems interesting to investigate this aspect in more detail with respect to the impact on the interaction (5) regarding the costs and (6) regarding the benefits in figure 1.

5 Conclusion

This paper was motivated to better conceptualise and support HRD's decision on competence development of knowledge workers and to present a decision model helping structure the decision about which worker's competences to develop with which learning measures, given a certain task or project. The model is intended to support KWPs identified in the organisations we analysed. Although the case study has provided us with a richer description of the decision context, similar work practices and processes have been described in the literature [21,25,35]. Thus, we are confident to address a problem that is important well beyond the scope of the organisations investigated in our case study, specifically in organisations in which HRD needs to justify decisions about training resources being allocated to the self-conscious and highly self-organised clientele of knowledge workers. Even if a mathematical model targeting the identified needs could be proposed, several obstacles and barriers occurring in an ICT roll-out could be identified. These challenges were discussed in detail taking the existing body of literature into account. Limitations of current operations research approaches could be identified in this regard and interesting research avenues have been identified. The next step in our research is to realise an ICT solution taking these challenges into account. Furthermore, the suitability of the proposed model will be demonstrated in a proof-of-concept study with the organisations analysed in the case study.

Concerning academic implications, our case study stresses the need to explore work practices on competence development deeper than has been done so far to render mathematical models useful. HRD has a tradition arguing against automatisms in resource allocation, often referencing the infeasibility to have all required data available or privacy issues. However, at the same time, talents and generally skilled workforces have already subscribed heavily to advanced knowledge infrastructures. This means that user-generated data and content can be used in a meaningful way, such as information about available and needed competencies as well as about measures that improve competencies produced by knowledge workers using enterprise knowledge infrastructures. In order to maintain talents and a skilled workforce, resource allocation for competence development needs to become increasingly recognised as an important decision that also involves taking into account this data and, in a fast-paced, innovative environment, this decision is also time-critical. The challenge requires agile IT support and has only just begun to affect academic discussions about what criteria to apply to justify resource allocation and at the same time foster commitment by knowledge workers.

Concerning managerial implications, the conditional requirements and needed data would be available, while the results have limitations in their expressiveness. Nevertheless, a final worker development decision currently remains in the hands of a HRD professional. However, the model supports analysing alternative options and helps justifying expenses for competence development. Within the discussion, we also critically reflected several constructs that were relevant to the organisations analysed, but could not be addressed in the present model due to the discussed organisational or technological limitations. Taking this as a "start-up" solution that can be well integrated into the current KWP, HRD is challenged to develop towards structuring and formalising its processes to increase traceability and justification of its decisions, and to get the most out of the information already available in CM systems.

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